STATE ENGINEERING EXPERIMENT STATION

The Research Engineer

GEORGIA SCHOOL OF TECHNOLOGY

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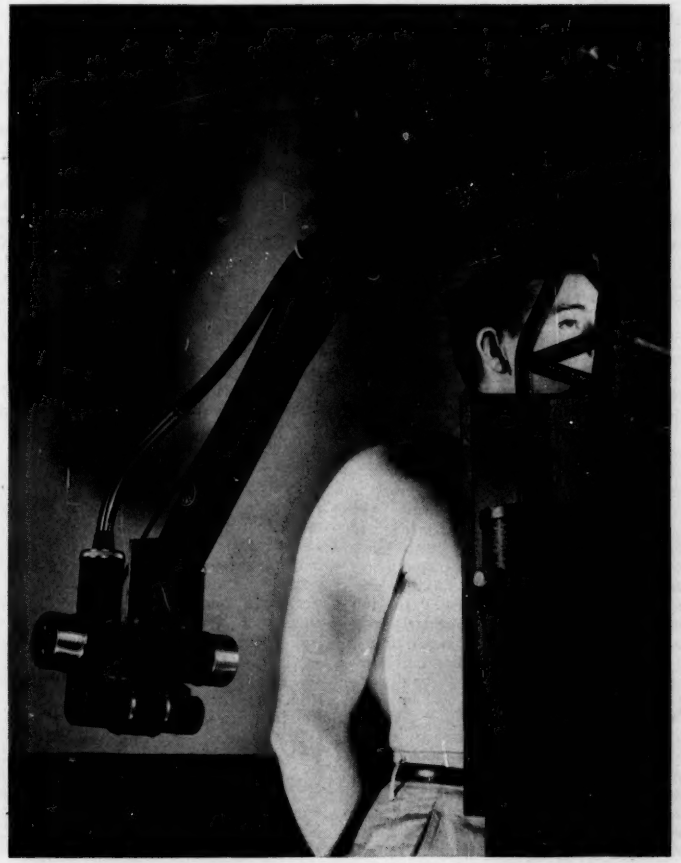

The Research Engineer

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TABLE OF CONTENTS

Portable Photo-Fluorographic X-Ray Equipment, by R. A. Hall and Calvin S. Hays 3
Cellulose and Wood—Georgia Resources, by Nathan Sugarman 7
Progress Report on Georgia Tech Food Freezing Research, by Thomas W. Kethley 11
Separation of Isotopes, by Dwight A. Hutchison 16
Report from the Library, by Dorothy M. Crosland 22

MEDICAL ENGINEERING

It is probable that the term "medical engineering" has had but little use, since medicine and engineering are generally considered entirely separate fields of science. This fallacy is based on a lack of appreciation of the fact that doctors require instruments and diagnostic apparati which have become highly complicated and which require the use of engineering design in their development and improvement.

Such scientific discoveries as the X-ray, the radioactivity of elements such as radium, and the principles of dielectric heating were quickly used by the medical profession in its unceasing fight against disease, both for research and for diagnosis. The sheer ponderosity of the early embodiments, however, was reflected in their high cost and consequent restricted availability. All too often, equipment design was performed by doctors who urgently required the apparatus and by mechanics and electricians who were unable, through lack of knowledge, to simplify and improve the rudimentary diagrams.

Even today, many improvements are being made on types of medical apparati which have been in use for decades, and some of these improvements are opening new fields of utility. Engineering design itself profited much through lessons forced upon it by the tempo of wartime operations, and benefits are now apparent in many fields.

Streamlining, different finishes, and more compact arrangement of components may seem of minor importance to the layman unless they happen to lower his doctor bill, but improved and more reliable operation over a wider range of conditions is something which he cannot ignore. Nor can he truly disregard the aforementioned structural changes; they may so alter the size and weight of equipment that previously heavy, stationary apparati may become available in portable sizes.

Such is the case with the recently developed portable photo-fluorographic X-ray equipment, described in the first article in this issue. "Modern design makes the big difference" here, as elsewhere, and sound scientific principles have been incorporated in a well-engineered embodiment which, being truly portable, can be used where previous equipment could not be taken.

Contributions to the health of this region are as much the concern of Georgia Tech as of any other institution, as witnessed by its courses in public health, sanitary engineering, and safety engineering. Through projects such as this, the work on frozen foods, and electron microscope studies on numerous biological problems, the State Engineering Experiment Station can lend its scientific and engineering facilities to a cause of importance to all.

PORTABLE PHOTO-FLUOROGRAPHIC X-RAY EQUIPMENT

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In line with its policy of assisting southern industry to gain "supremacy through research," the State Engineering Experiment Station has recently completed work on the design and development of a portable photo-fluorographic X-ray unit in conjunction with an Atlanta X-ray equipment company. Designed primarily for making chest X-rays in the tubercular case-finding programs of public health agencies, this machine, pictured in Figure 1, features high speed operation combined with light weight and portability. It is, therefore, particularly suitable for use in mass surveys of employees in industry, students in schools and colleges, and other such groups.

The discovery of X-rays by Roentgen in 1895 marked the introduction of a new and useful scientific tool. It may even be said that the X-ray is the key which has opened

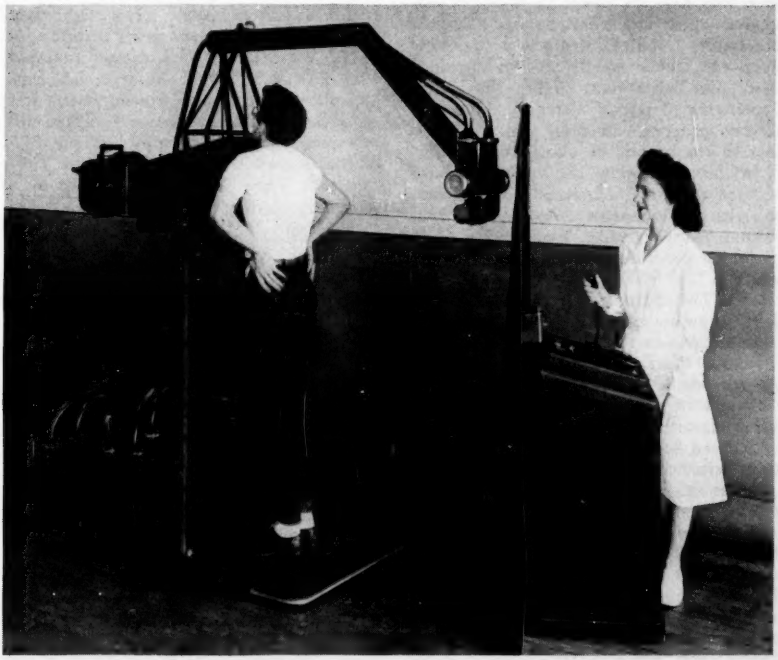

Figure 1. Portable photo-fluoroscopic X-ray equipment in operation.

the door not only to our present-day knowledge of the structure of the atom but also to the use of atomic energy itself.

X-rays are emitted when a high voltage current (stream of electrons) passing through a vacuum is allowed to strike the face of an electrode. In practice, this electrode is usually made of tungsten and is inclined in such a way that the rays emitted are directed through a window in the side of the evacuated tube.

Although X-rays are invisible, they are closely akin to light in that they are propagated by transverse motion and travel in straight lines at the speed of light (186,300 miles per second); they also affect photographic plates in a similar manner. Their principal difference from light lies in their extremely short wave-length, which ranges from 1/500,000 to 1/5,000,000,000 of an inch—approximately 1/5,000 the wavelength of visible light. More important, these rays have the power to penetrate substances which are otherwise opaque, their penetrating ability depending generally upon the atomic weight of the substance. Also, like ultra-violet light, they cause fluorescence of certain materials. These latter two properties are those which are utilized in the process of photo-fluorography.

In this application, the subject is placed between an X-ray source and a screen coated with a fluorescent substance, such as barium platinocyanide. X-rays directed at the object produce an X-ray shadow-image, which is then photographed by means of a camera. The advantages of this method over direct exposure of photographic plates for large-group surveys are obvious: the quantity (and hence the cost) of film required can be reduced to that minimum which is consistent with readability, and, by the use of an automatic roll film camera with a high speed lens, examinations can be made at an extremely rapid rate.

When this new X-ray machine, as many as 300 chest photographs per hour can be recorded on 70 mm roll film, producing 2½" x 2⅞" images which may be examined without enlargement. Total weight of the entire unit is 650 pounds—*about 1000 pounds less than the lightest standard equipment previously available for this purpose.* The various components are designed to permit quick assembly and disassembly without the use of tools, so that the machine may easily be unloaded, set up, and put into operation in less than fifteen minutes. The size of each component is such that it may be handled by one or two men and stowed conveniently inside the average panel body truck or station wagon. During initial tests, the machine was transported some 600 miles in a two-door sedan without damage either to itself or to the automobile.

DESCRIPTION OF MACHINE

Basically, the machine is similar to other standard photo-fluorographic units which utilize electronic control of exposure time. Radiation is obtained from an Aeromax No. 12 air cooled X-ray tube, energized by a high tension transformer delivering 60 milliamperes of full wave direct current at 90 peak kilovolts. The X-ray image is formed 40 inches away on a 14" x 17" fluorescent screen inside of a light-tight metal hood, which supports a Fairchild type F-212 70 mm roll film camera equipped with a Kodak X-Ray Ektar f 1.5 lens. The photograph made of the fluorescent image is later examined and may be retained as a permanent record; approximately 375 exposures may be made on a single 100-foot roll. These are readily identified by a simple numbering device which is attached to the front of the screen in such a way that it records on each film.

Once set up, operation of the machine is entirely automatic, requiring the use of only one control by the technician. This push-button applies the high voltage to the X-ray tube which starts the exposure. Part of the light from the fluorescent image is then picked up and integrated by an RCA 931-A photo cell mounted inside of the camera hood. The function of this cell is to de-energize the X-ray tube when the proper amount of light has reached the film. Thus an effective exposure control is produced which automatically allows for variation in the thickness of individual chests, intensity of radiation, and other factors which may affect the illumination of the screen. This circuit, together with its related amplifier, is known as the Morgan timer. The timers used here were developed under a license from the inventors. After

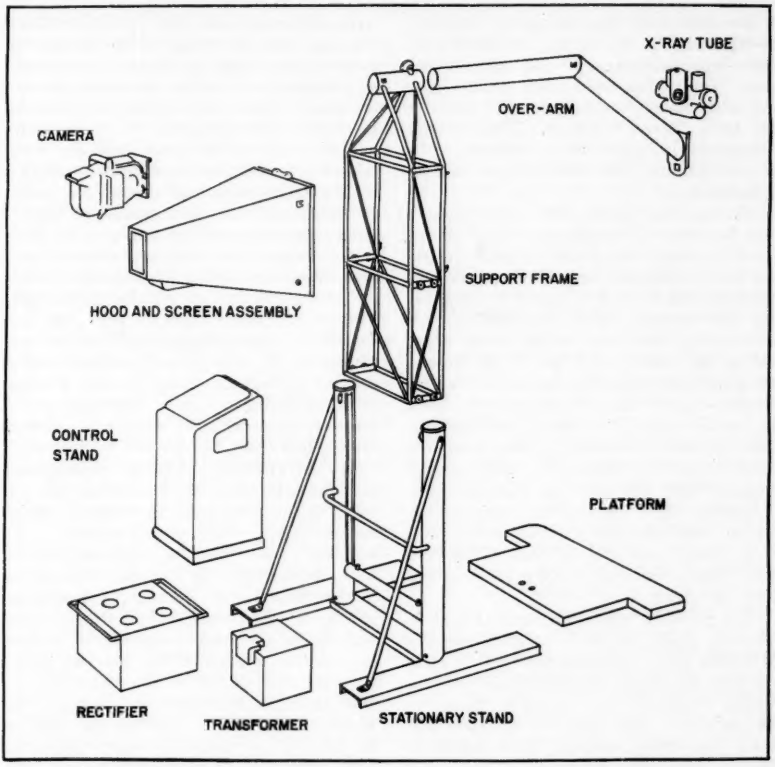

Figure 2. Exploded view of machine, showing method of disassembly.

each exposure, the film is automatically advanced in the camera.

The normal exposure time is approximately one-half second. However, should the Morgan timer fail to operate after one and three-quarter seconds, the tube is de-energized by means of a mechanical safety timer interlocked within the circuit, and a warning buzzer is sounded to indicate that something is wrong. If the electronic timer is found to be out of order, the mechanical timer may be manually set in order to complete a survey.

The development of this equipment has been principally the work of four men: Dr. Gerald A. Rosselot, director of the State Engineering Experiment Station, Messrs. B. J. Dasher and N. R. Henry of the Station's research staff, and Mr. C. S. Hays of the S. & H. X-Ray Company. At the request of Dr. Rufus F. Payne, who, while acting as special consultant for the Georgia State Board of Health in 1944, had sensed the need for a truly "portable" chest X-ray machine, a study was made of existing apparatus to determine which portions could best be redesigned to eliminate excess weight. This led to the conclusion that the majority of dead weight occurred in two items: namely, the camera- and tube-supporting frameworks and the high-tension rectifier. Accordingly, a light-weight steel tubular framework was designed which supports the camera, fluorescent screen, and

X-ray tube in a single assembly weighing 144 pounds. Of this figure, the framework itself represents only 29 pounds. At the same time, a specially constructed light-weight rectifier was designed and built by the local X-ray company. This rectifier weighs only 170 pounds as compared with an average of 250 pounds for existing equipment.

The camera, screen, and tube support may be raised or lowered at a touch of the hand through a range of 24 inches, in order to accommodate individuals of various heights. This is made possible by suspending the assembly with two flexible steel cables which run over pulleys in the upper end of the tubular uprights of the stationary stand and connect to concealed counterweights inside. Ball-bearing rollers riding on vertical rails formed from stainless steel sheet provide a smooth motion over the entire range of adjustment. Soft rubber bumpers limit the travel in each direction.

During transportation, the equipment is divided into ten easily separable units, each of a weight that can be handled by two men. These units are shown in simplified form in Figure 2.

One problem which was encountered in the early design stages was the maintenance of correct focus and alignment of the camera with the screen and tube during service. Special attention was therefore given to the design of quick-assembly features. The hood and screen assembly is mounted on two stainless steel trunnions at the lower front corners, permitting it to be set in position by placing the trunnions into hooks welded to the tubular support frame. Two aligning stops at the upper front corners of the hood then engage latch pins which hold them in place. The camera is mounted on a grooved adapter plate, permitting it to slide vertically into place on the rear end of the hood. This provides a rigid attachment which is also light-tight. A similar sliding plate is used to support the X-ray tube, except that no light seal is provided. The large tubular over-arm is inserted into a horizontal socket on top of the hood support framework; an index pin insures proper alignment, and a lock knob secures it in place.

The counterweight cables are attached to the lower end of the movable support frame by means of steel terminals which slip into special fittings. This allows the movable frame to be quickly disconnected and withdrawn as a unit from the stationary stand. The counterweights may then be lifted out of the uprights or, as is customary, they may be left inside and the stand moved intact without further disassembly.

The transformer and rectifier are separate units and are easily connected by inserting the various cables into sockets; these are so designed that it is impossible to connect them improperly. The operator's control stand contains, in addition to the milliammeter, kilovoltmeter, and selector switches, a line voltage stabilizer and the Morgan timer, and space is provided within the bottom of the stand for the stowage of cables during transport. Provision is also made to adapt the machine to any standard line voltage from 100 to 250 volts.

In the fall of 1945, an experimental machine was taken to Savannah, Georgia, where it was employed in a public health survey along with other equipment of standard make. Results of these original tests, while revealing the need for several improvements, were definitely encouraging. Primarily, the machine had demonstrated that X-ray equipment need not be massive in order to withstand the wear of everyday use. Furthermore, the flexibility of this small, light-weight unit opened up new fields for X-ray examination, such as in smaller communities and industries where the number of people did not formerly justify the setting up of cumbersome equipment.

At the conclusion of the Savannah survey, the machine was returned to Atlanta and modified to incorporate the improvements suggested by the service test. These consisted essentially of redesigning the over-arm for increased rigidity and the addition of a low wooden platform to prevent tripping over the legs of the base stand. At the same time, work was begun on a second unit for the purpose of developing such special tools and fixtures as would be required for manufacture of these machines by industry. To supplement this, a complete set of production drawings was made, showing the detailed construction of each part along with all circuit diagrams. A set of trouble-shooting instructions was also

prepared for the electrical apparatus.

Since the majority of the supporting structure is brazed of cold drawn seamless steel tubing, the problem of providing interchangeability of parts was encountered, because of shrinkage of the tubes after brazing. This was overcome by construction of locating fixtures for all major assemblies: these were made of structural steel channels and were designed to permit easy access to all joints. As a further precaution against warping, a special low-temperature brazing alloy was used at critical points to insure application of the smallest possible amount of heat.

A steel die was made for use in forming the vertical rails, which guide the motion of the camera and screen assembly. This die may be inserted in any large capacity power brake to form 16 gauge stainless steel blanks into the specially shaped hollow section on which the ball-bearing rollers travel.

The second (or developmental) machine, together with the production tools, was completed in March, 1946. Test runs in the laboratory indicated a definite improvement over the original unit, particularly in the ease of operation and rigidity of the support structure. General appearance was likewise improved through the use of a black wrinkle finish and plated fittings.

With basic development thus completed, it was felt that southern industry would have little trouble in producing this machine, and under normal conditions this would undoubtedly have been true. However, after contacting local manufacturers it was discovered that, because of the almost universal material shortages and uncertainties of the current reconversion period, none of these manufacturers was willing to bid unless more definite information could be supplied regarding the amount of labor and materials required. Since only two machines had been built, and these while the design was still in the fluid stage, there was no reliable way to estimate what the machine would cost in commercial production. Accordingly, it was decided to set up a pilot program calling for the construction of several additional machines, to be built and assembled in the fixtures similar to the manner in which they would be handled in a factory. A record of all labor and material expenses would then provide a reasonable basis for forecasting the cost of a production run. This pilot run was completed in June, 1946.

At the present time, all of the machines are in use. The original model has been in the service of the Spartanburg County (S. C.) Tuberculosis Association since January, 1946, completing nearly 30,000 exposures without failure. In another recent survey conducted by the Georgia State Board of Health, the entire population of the city af Macon was examined, using a group of five of these machines. This survey required more than 60,000 exposures.

Truly portable photo-fluorographic X-ray machines should prove of considerable utility. The health of its citizens is at least a partial responsibility of each state, hence assistance in the development of equipment of this type is a logical responsibility of the State Engineering Experiment Station.

CELLULOSE AND WOOD—GEORGIA RESOURCES

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CELLULOSE

Most of our natural raw materials are subject to continuous depletion because of the heavy demands of modern civilization and war. Even where the reserves of many of these materials may still be very large,

their replenishment may be taking place at an extremely slow rate, or not at all.

There is, however, one natural resource of great industrial importance which is capable of being continuously replenished. This very important raw material is cellulose.

Cellulose is the predominating constituent of plant tissues. In the natural state, the cotton hair, containing about 90 per cent, is the purest form of cellulose, and this material can be further purified to yield a cellulose of better than 99.5 per cent purity. The greatest bulk of cellulose, however, occurs in the form of wood, which contains approximately 60 per cent.

Basic chemical knowledge of the structure of the cellulose molecule was obtained by Flechsig (1883), Haworth (1926), Sponsler and Dore (1926), and Haworth and Machemer (1932). Their studies showed that celluloses, regardless of source, are all chemically similar. There may be differences due to varying molecular weights and molecular weight distributions, but all of the cellulose molecules consist of anhydroglucose residues which are linked together in long chains. It is by virtue of its high polymeric, long-chain nature and its organization into fibrous form that cellulose has such great importance as an industrial raw material.

As mentioned, the molecular chains are not all of the same length, even in a given sample of cellulose, and the distribution of chain lengths may vary according to the origin of the sample and the treatment it has received. The D.P. of a cellulose polymer—degree of polymerization, or number of repeating structural (anhydroglucose) units in the chain—varies widely. Native cellulose fibers may have a D.P. of 2,000-3,000; wood pulp, 700-900; and viscose rayon, 300-450.

Physical properties of celluloses are closely related to the D.P. Those of low D.P. (1-10) have no film-forming properties, for example; good, strong films can be made from those of 50-500 D.P.; and celluloses of 500-2,000 D.P. yield excellent films. The last group may appear as long fibers; the intermediate as short fibers; and the lowest group as a powder.

While pure glucose has five reactive hydroxyl groups, each anhydroglucose unit in the cellulose chain possesses only three hydroxyl groups which are still available for chemical reaction. These may be esterified with acids, reacted with alcohols to yield ethers, etc. Many of the derivatives formed are important products used as rayons, surface coatings, and plastics.

Properties of these derivatives vary with the completeness of the reaction. A completely nitrated cellulose, for example, would contain 14.14 per cent nitrogen, but the highest commercial nitrogen content is 13.5 per cent. Guncotton ranges from 12.5-13.5 per cent nitrogen; cellulose nitrate for films, rayon, lacquers, coated fabrics, and cements from 11.2-12.3 per cent; and cellulose nitrate for celluloid plastics from 10.7-11.2 per cent.

Of the organic esters, the acetate is of the greatest present importance, particularly the secondary acetate which contains an average of 2.5 acetyl groups per glucose residue. This secondary acetate, soluble in acetone, is used in the manufacture of acetate rayon.

Other cellulose esters have been prepared, such as the propionate, butyrate, and those of higher fatty acids. Mixed esters may also be prepared, some of them finding wide application in the plastics field; one example is cellulose acetate-butyrate. Mixed esters have wider solubility ranges and other enhanced physical properties.

The cellulose ethers are generally produced by the reaction of the alkyl sulfate or chloride with alkali cellulose. These cellulose ethers are more resistant to hydrolysis than the esters and are hence more stable toward acids and alkalies. Methyl cellulose and ethyl cellulose find wide application in lacquers and plastics.

A very important cellulose derivative is the xanthate, which may be dissolved in dilute alkali and extruded into an acid solution, forming filaments of viscose rayon. This xanthate is made by reacting alkali cellulose with carbon disulfide.

In addition to the reactions involved in the formation of such derivatives as esters and ethers, cellulose may also undergo hydrolysis (in the presence of dilute acids) and oxidation (in the presence of oxidizing agents). These oxidation and hydrolysis reactions are avoided as far as possible in

industrial cellulose operations, since they cause reduction in strength.

WOOD

Wood itself is a versatile material, in addition to being an abundant source of cellulose. By virtue of its physical structure and chemical composition, it lends itself to many applications. It finds use in its rough or natural state, in the form of lumber and lumber products, and, following chemical breakdown, in the form of one or more of its chemical constituents. As a structural material it can be easily sawed, planed, shaped, steamed, bent, plasticized, molded, fabricated, and assembled by means of nails, screws, and glues. Wood can be pulped by various chemical processes to yield its cellulose, which can further be converted into chemical cellulose derivatives or into the many pulp and paper products. It can be partially decomposed by heat to yield useful chemicals such as acetic acid, acetone, and methanol (wood alcohol), in addition to, according to the species of wood, such other products as pine oils and turpentine.

Chemically, wood is composed of a small fraction (1.0 per cent) of ash-forming minerals, 18 to 27 per cent of lignin, and 70 to 80 per cent of holo-cellulose, which consists of alpha-cellulose and hemicellulose. These components are organized into the cellular structure of the wood, the cellulose being the principal constituent of the cellular (fibrous) material, and the lignin acting mainly as a cementing and hardening material for the cells.

The variations in cellular structure of the thousands of species of wood give rise to an almost limitless selection of properties from which to choose for a particular use. Many of these species have very desirable qualities, but all have one great inherent fault—they are hygroscopic.

When wood is in contact with the surrounding air, it reaches an equilibrium moisture content depending upon the relative humidity of that air. An increase in water content causes swelling, while a decrease causes shrinking. This dimensional instability, dependent upon the moisture content, is one of the chief drawbacks in the use of wood.

So far at least, no one has been able to eliminate entirely this defect in wood. Simply heating dry wood will reduce the swelling, but this treatment also had a weakening effect. The U. S. Forest Products Laboratory has had partial success in reducing swelling by the treatment of wood with water-soluble phenol-formaldehyde resins which, when heated, react with the cellulose molecules themselves. A somewhat similar treatment using methylolurea has been developed by du Pont, the product being called "Transmuted Wood"; further engineering research on this latter method has been conducted at the State Engineering Experiment Station.

CELLULOSE AND WOOD RESEARCH

A great amount of research on cellulose and wood has already been performed, but much needed research remains to be done. For example, the size and structure of the cellulose molecule need further investigation, as do the chemical differences between celluloses from different sources. Another important topic which is undergoing investigation at present but needs still further research is the oxidation of cellulose. Further studies are needed on the reactions of the hydroxyl groups and the formation of new cellulose derivatives. Of considerable interest is the possibility of preparing derivatives containing primary cross-linkages between adjacent cellulose chains.

Another interesting project would be a study of the fundamental characteristics of cellulosic fibers from different plants. When the factors which determine the character of a cotton fiber and differentiate it from a wood or ramie fiber are thoroughly understood, it should be possible to develop more desirable characteristics. Such a study would include an analysis of the microscopic, micellar, and molecular structures; the distribution and character of non-cellulosic components; the physical properties of the fibers; and an analysis of those factors of structure which determine the strength, stretch, and pliability.

Any broad research on cellulose must of necessity deal extensively with cotton. In such a program, emphasis would be placed on finishes and treatments which would enhance the useful properties of cotton. Such studies would include bleaching, mercerization, permanent shrinking, water-

proofing, development of crease resistance, and the use of special finishes and treatments.

In the field of wood and forest products, there is a multitude of topics on which research is needed. These problems range all the way from studies of the structure, identification, and properties of wood through timber physics and mechanics to projects on chemical utilization and the utilization of wastes. Listed below are a number of selected topics of particular interest:

1. Research on the chemical seasoning of wood (steeping wood in chemical solutions before kiln-drying).

2. Development of effective moisture-excluding coatings, such as sealers, repellents, varnishes, paints, lacquers, special chemicals, etc.

3. Work on effective impregnants to prevent the shrinking and swelling of wood, including further experimentation on presently known treating possibilities of any promise, such as resin impregnation and treatment with formaldehyde or acetic anhydride.

4. Research on oils, gums, tannins, and other extractives of wood.

5. Development of improved methods of distillation of both hardwoods and softwoods, such as vacuum distillation and the use of gaseous heating mediums or catalyzers.

6. Work on the possibilities of the heat treatment of wood at temperatures below those of ordinary distillation, in order to produce old and new distillation products and residues suitable for plastics, hydrogenation, and high quality fuel.

7. Fundamental and applied work on lignin.

8. Development of pulping processes which require small capital outlays for installation at medium-sized wood fabricating plants. Such pulp mills should utilize that part of the plant "waste" which is in large enough particles to provide good fibers.

9. Development of pulping processes and products which can include the bark.

10. Design of machinery for defiberizing or chipping wood as close to the forest as possible, in order to permit handling of that rough and small material which is normally left in the woods.

The above topics merely suggest a few of the many lines of research on forest products which need to be followed.

GEORGIA TECH'S PROGRAM

That cotton and the pine tree are two of Georgia's principal resources is an accepted fact which requires no statistics to prove. It is true that cotton has suffered from competition with other fibers, but this is the more reason for vigorous research on its properties and applications. On the other hand, the pine tree, by virtue of its rapid growth, is in a favored position, particularly as a source of pulpwood for kraft paper. However, much research yet remains to be performed on the use of pine tree products before they can be exploited to the greatest economic advantage.

Georgia Tech has long recognized the importance of these resources to Georgia and already has a record of endeavor in this field. For example, a project was started in 1934 on the utilization of Georgia pine pulp for viscose rayon. It was shown that rayon could very satisfactorily be made from this material. Among other projects involving cellulosic textile fibers have been those on cotton spinning and on the processing of domestic flax for textile use. In 1936, some work was done on the impregnation of pine wood with rosin, and, much more recently, engineering research on the resin-impregnation of wood has been performed at the State Engineering Experiment Station.

In keeping with the increasing emphasis on research at Georgia Tech and the development of the graduate school, an expanded program on cellulose and wood is now being planned. Work is already in progress on a study of oxidized cellulose and its derivatives. Preliminary investigations of an exploratory nature are being made on the use of liquid sulfur dioxide and liquid ammonia as solvents for the impregnation of wood.

In order to better prepare students for research in this field, courses in cellulose chemistry have been organized, and it is hoped to augment these later with applied courses in wood chemistry.

Cellulose and forest products are already important resources of the state, but these materials, through the application of both fundamental and applied research, are certainly capable of yielding even greater returns to the people of Georgia. The problems involved are not restricted in interest to this state alone, however, and research on them, it is hoped, will be a contribution to the national welfare.

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PROGRESS REPORT ON GEORGIA TECH FOOD FREEZING RESEARCH

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Frozen foods, today, appear on almost every table. They are enthusiastically welcomed by the housewife who, when using them, is relieved of the preparation work required for the use of many fresh edibles. Furthermore, the apparently higher cost of some frozen foods is usually offset by the lack of waste involved in not having to purchase stems, leaves, etc., and by the time saved in preparing them for cooking or serving.

In addition to these practical advantages, which account for the high sales appeal of frozen foods, there are other advantages of far greater economic significance. First of all, the proper location of freezing plants enables the farmers of a region to harvest their perishable crops and get them to market without the high spoilage factor involved in shipping them "fresh." Secondly, crops may be gathered at full maturity instead of "green," so that better quality is provided. Thirdly, crops of such high perishability that their present markets are strictly regional may be made available to the tables of the nation, and new demands thus created.

All of these factors are of particular importance to the agricultural South which is, by virtue of its climate, a natural home for the frozen foods industry and, by virtue of its growing economic development, a logical place for the establishment of large new industries. Not that food freezing is not already a large industry; it is, but its potentialities are far from exhausted.

Because of its interest in the development of both industry and agriculture in Georgia and the Southeast, the State Engineering Experiment Station of the Georgia School of Technology has long been interested in the possibilities offered by frozen foods. While much research has already been conducted elsewhere, very little correlation appears to exist between many experiments, and much developmental work has yet to be accomplished on freezing processes. It was for all these reasons, then, that the present program on the preservation of foods by freezing, jointly sponsored by the

Tennessee Valley Authority, was inaugurated at the beginning of this year.

PRELIMINARY PROJECT ANALYSIS

Once a process has been established as feasible, there is a tendency for further improvements to be limited to immediate and practical changes, and interest in the fundamental and theoretical aspects becomes proportionately less. However, until the fund of basic knowledge concerning a process becomes sufficiently large to enable workers to predict the probable effect of variations, progress is usually haphazard and erratic. Although our present knowledge of foods and their preservation by freezing is wide and diverse, there nevertheless remain many gaps which have yet to be closed before we can be assured that we have attained near-perfection in this field.

Undeniably, there is always a temptation to attack a problem entirely in a practical manner, with a view toward its immediate solution. All too often, however, excessive time, energy, and money have been spent in this manner without advancing the knowledge of the process in any material way. On the other hand, basic and fundamental knowledge, even if it appears to have no immediate application, ultimately becomes useful in the light of other and more recent advances. A good example of this in the field of food preservation by freezing is the prevention of discoloration of certain varieties of peaches by the addition of ascorbic acid before freezing. Until a thorough study of the problem had shown that the discoloration was due to oxidation, and that it could be prevented, the consensus was that peaches would discolor and that nothing could be done about it.

Viewing the problems of the field in this manner, certain aspects of food preservation by freezing seem to warrant a critical evaluation of the present knowledge and a thorough investigation in the belief that fundamental studies will yield information that can later be applied to working practice.

This project has therefore been set up to include the investigation of problems of this nature. One of the ultimate objectives is the development of an inexpensive freezer of high volumetric capacity, so that small communities will be enabled to process their own fruits and vegetables. This work is being outlined on a long term basis, and the final criterion for selection of problems for investigation has been the physical equipment and personnel potentialities which are available.

CHEMICAL AND BIOLOGICAL PROBLEMS

The present program calls for the study of those chemical and biological problems which appear to offer the greatest possibilities of advancing our knowledge and improving our process practices.

Colloid systems are basic in the physico-chemical structure of living matter. These delicate systems are strongly affected by radical changes in temperature, sometimes in an irreversible manner. Much work on colloids has been performed, but investigations dealing with colloidal aspects of food freezing have so far been inconclusive. For example, there are no complete data which indicate the lowest temperature to which various foods can be subjected without irreversibly affecting their colloid systems by freezing out the bound water associated with the protein molecules. Certainly, no systematic study has ever been made to show the relation between actual temperatures inside the food particles and changes in the colloid systems. Conversely, there is only meager information available to show how much freezing can take place and yet allow the water to return to its original locus by controlled thawing. It is thought that slow thawing will allow a more complete return of water to its proper place, yet quick thawing by high frequency and infrared treatment has recently been given considerable attention.

Directly connected with this problem are the heat transfer characteristics of foods. If the minimum allowable temperature which can be achieved within the food particle without irreversibly freezing out the bound water can be determined, it will then be necessary also to know the exact heat transfer characteristics for various foods in order to predict the optimum time at the allowable temperature to effect freezing within the foods.

OTHER PROBLEMS

In connection with these problems, it will also be necessary to perfect a number of

techniques in order to evaluate findings more critically. For example, it has been shown that there is a relation between chemical change and color change in foods during processing. Further research on food freezing demands more accurate and specific methods for determining color changes, particularly on the gross specimen. In this same class of problems are those relating to the study of the growth of ice crystals. Certain investigations of the structure of ice crystals have been made, but, thus far, the data do not indicate any possible relation between the growth of crystals and chemical and physical structures, or any subsequent changes associated with crystal formation. New techniques may make it possible to accumulate data which will assist in setting up criteria for the optimum conditions under which various foods should be frozen.

Other aspects of these problems are even more basic and, therefore, should be investigated and correlated in order to facilitate the application of knowledge to actual practice. Color changes which occur during processing, freezing, and storage are caused by specific factors. Unfortunately, however, present knowledge of the chemistry of natural pigments is not yet sufficiently adequate to enable us to determine exactly what causes these changes in all cases. As soon as we discover the underlying causes, a solution to the problem will be much nearer at hand. This interest in food color is a result of consumer choice; that is, the consumer of frozen food prefers the natural, fresh-appearing frozen food to the off-color product.

During processing, freezing, and storage, other possible changes in the composition of foods (which are not so evident but which are of much greater importance to the consumer) concern the nutritional values, including the vitamins as well as the calorific materials. Determination of these values is essential in any study of frozen foods, even if it is merely as an index to possible change. One nutritional aspect which has received little attention is that of

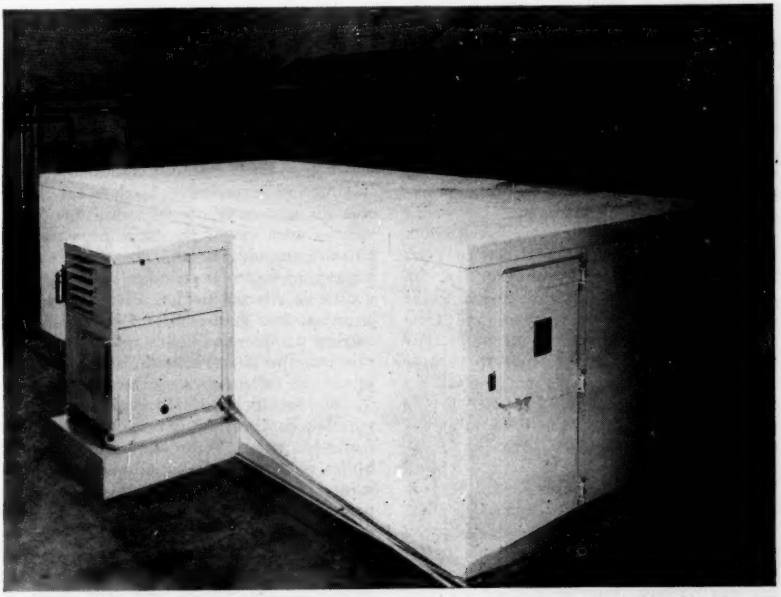

Figure 1. Exterior view of refrigerated work room and storage chamber. A work floor for food preparation work will be constructed above these rooms.

the effect of protein denaturation. When enzymes are inactivated by blanching or by other means, proteins are denatured. Further data on the effect of this change on the nutritional value of foods so treated would be a welcome addition to our present knowledge.

In addition to the more fundamental problems directly associated with the chemical and biological aspects of the preservation of foods by freezing, there are also some immediate and practical problems which should be solved before we can make any radical developments in the freezing process. These include a critical study of potential solvents for use in immersion freezing, more information on optimum conditions for the storage of frozen foods, and perfected packaging for frozen foods, with consideration for both storage and consumer interests. Another practical problem of this nature is concerned with the proper stage of maturity and the varietal selection of the foods most suitable for freezing.

PROCESSING OF FOODS PRIOR TO FREEZING

Another large category of problems is concerned with the processing of foods prior to freezing. There are possibilities of many new developments in this particular field, and more and more importance is being attached to it as increasing information reveals the many detrimental changes which can take place during processing. Although the blanching of foods to inactivate enzymes has been accomplished traditionally by steam or hot water, there is much to be learned concerning proper times and temperatures for processing various foods. Because hot water or steam tends to damage many foods, interest has been aroused in other methods of blanching, such as the use of high frequencies. The meager knowledge available in this field, however, indicates that the equipment for successful blanching by high frequency will be very expensive and difficult to control.

Closely allied to such methods of energy transfer to inactivate enzymes and to kill microorganisms is the use of chemical agents for this purpose. Enzyme systems are very delicate and respond readily to treatment with many chemical agents. Much new evidence has become available on chemical agents for the inactivation of enzyme systems, and a reinvestigation of this field may well give us some indication of how to process foods without causing mechanical damage.

Many other problems warrant investigation, but those which have been touched upon here seem to offer the greatest promise of return to both producer and consumer.

ENGINEERING PROBLEMS

Many engineering problems have had to be attacked before this experimental work could be started. These have concerned the design and construction of pilot plant equipment which is sufficiently flexible in operation for the experimental processing of foods, lay-out designs, and design of the cold rooms for storage and working space. All of these phases of the problem have been completed, except for the fabrication of a few parts.

As work goes forward on the experimental problems, new findings will be translated into engineering practice as rapidly as possible. This article has deliberately neglected engineering and equipment aspects, since as yet no new achievements have been made here in these fields.

PERSONNEL

In order to investigate the problems which have been discussed above, the State Engineering Experiment Station has available the services of its permanent staff and various members of the faculty, as well as outside consultants and the advice and counsel of other experiment stations. The project is directed by Dr. Frederick Bellinger, Associate Professor of Chemical Engineering at Georgia Tech, and three members of the Station staff have been assigned to full-time work on the project: T. W. Kethley, Research Assistant Professor; W. B. Cown, Research Assistant; and Doris M. Street, Technical Assistant. R. N. Miller of the Chemical Engineering Department has been assigned to the project on a part time basis. In addition to this group, which is concerned mainly with the development of the problems of quick freezing, there are available to the project all the services of the Station, especially those of R. A. Hall, chief of the Station's Engineering Section.

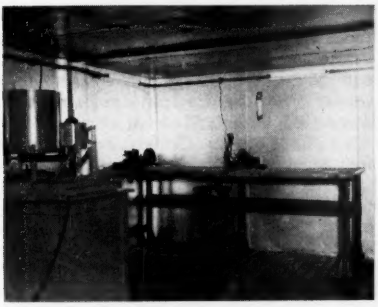

Figure 2. Partial view of refrigerated work room.

EQUIPMENT

Since the State Engineering Experiment Station has envisioned a long term research study of the problems of food preservation by freezing, it has already secured or has fabricated equipment which can be used for this research work or for pilot plant operations. Considerable refrigeration equipment has been purchased and has now been installed.

The majority of the work which will be performed on the study of the preservation of foods by freezing will be conducted in the large refrigerated room shown in Figure 1. This room is 12 feet wide, 27 feet long, and 7 feet high, and is built in two sections. One of these sections, 9 by 12 feet in size, will serve as a storage room, being kept at 0° F. by a 7.5 hp. compressor; this section also has a 7.5 hp. compressor, driven by a gasoline motor, which will maintain the temperature of the room if the operating compressor should fail. The main section of the refrigerated room, shown in Figure 2, is 12 by 18 feet; its temperature will be maintained at 18-20° F., or similar temperatures below 32° F., by a single 7.5 hp. compressor. In this room will be located the equipment for examination of frozen materials and the experimental freezers.

There is also a 6 by 8 foot walk-in cooler which will be maintained at various temperatures for experimental storage and freezing operations. This box is refrigerated by a 3 hp. compressor. An air-conditioned dark room is kept at 68° F., the optimum temperature for the development of color photographs of frozen foods.

A small immersion freezer of one-gallon capacity, shown in Figure 3, has been designed in accordance with the principles of the immersion freezer developed by the Tennessee Valley Authority; it will be used in the cold room to gather information on immersion media, also such information as may lead to improvements in design. An experimental blancher, quencher, and centrifuge for continuous operations have been designed and fabricated at the Station. Each of these has been designed so as to allow variations in the treatment of foods, in order that the equipment may handle small amounts of food or as much as 200 pounds per hour.

THE LITERATURE SURVEY

A literature survey is a necessary part of any research project, since it is always desirable to know what has been done on any related phase. The *Literature Search on the Preservation of Foods by Freezing* was prepared by the Station's Technical Information Division, under the direction of

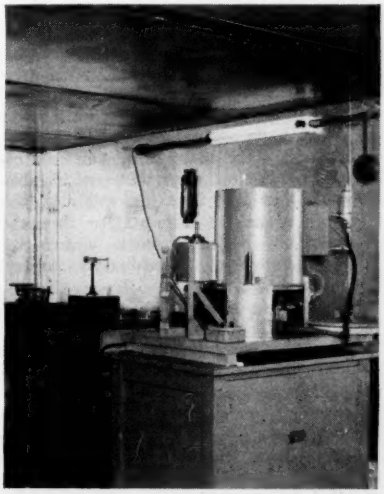

Figure 3. Another view of refrigerated work room, with the small immersion freezer in the foreground.

B. H. Weil, and has been published as State Engineering Experiment Station Special Report No. 23; this report was abstracted in the September issue of THE RESEARCH ENGINEER. Copies of this search have been made available, at cost, to other workers in this field.

FUTURE PLANS

Georgia Tech research on food freezing is still in its initial phases, but considerable equipment has been installed, and work on several problems is now in progress. Frozen foods are of definite importance to this state and region, a fact which has been recognized by both the Tennessee Valley Authority and the Engineering Experiment Station of Georgia Tech in the establishment of the project. Georgia Tech is therefore more than anxious to assume its responsibility for the engineering and corequisite research which is certainly required for the production of better products in the best possible manner.

SEPARATION OF ISOTOPES

By DWIGHT A. HUTCHISON
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Isotopes, during the past year, have become almost a matter for everyday conversation, because of the highly explosive nature of one of the isotopes of uranium. Only a few years ago, however, few people, including scientists, would have attached much practical significance to the availability of separated isotopes of *any* element, particularly those of uranium. As is well known, however, U-235, the relatively obscure isotope of a few years ago, has expanded its domain to affect the affairs of all countries of the earth, bringing home with considerable force the fact that it is impossible at the inception of any experimental or theoretical problem in fundamental research to predict the scope of the results which may be obtained.

VALUE OF FUNDAMENTAL RESEARCH

In recent years, there has been a tendency to justify science on the basis of its immediate practical applications to wartime pursuits or to the solution of peacetime industrial problems. Regardless of this, it has never been the primary aim of pure science to obtain results which must have immediate practical utility; instead, scientists engaged in fundamental research have pursued a disinterested course—one of satisfying well-founded curiosities concerning the fundamental aspects of natural phenomena. These scientists, in the gradual process of pursuing such a course, have increased our command of the material world in a striking fashion.

Indeed, it is unfortunate that a major part of industry does not realize that the wondrous creations of its laboratories are based almost wholly on the results of fundamental research. Some people are of the opinion, furthermore, that this lack of understanding is increasingly permeating academic institutions, especially those concerned with the technological aspects of science. Without the theorists and experimentalists of the pure sciences, industrial technology would still be in a primitive stage of development, yet administrators of some academic institutions apparently fail to realize this fact.

From a strictly *intellectual* point of view, applied science, with its utilitarian aims, has been ranked below so-called pure science. Regardless of any such ranking, all of us will agree that applied science is a form of intellectual activity which seeks by quite ingenious methods to overcome practical obstacles. Modern civilization requires a state in which there is a harmonious blend-

ing of the pure and applied sciences into a cooperative effort.

By way of analogy, we might remember that one of the primary requirements for a good harvest of Georgia peaches in future years is the existence of healthy peach seeds today. It is true that the seedlings may die in transplanting to the future orchard, because of adverse natural forces; or, at a later stage of growth, the peach blossoms may be destroyed by a late frost. These causes of death to the potentialities of the peach seed may be to some extent controllable, but it remains an indisputable fact that the peach seed of fundamental research is an essential requirement for the bounteous peach crop of applied technology.

Georgia Tech, realizing the interdependence of pure and applied research, has therefore encouraged work along a number of lines of fundamental research, one of which is the subject of this article.

METHODS OF SEPARATING ISOTOPES

The separation of isotopes, which by definition are species of a chemical element which differ in mass but not in chemical properties, has been one of the more interesting fields of fundamental research for the past fifteen years. Within the last few years, however, separated isotopes have taken on increased practical significance, as evidenced by the present commercial production of N-15 and C-13 concentrates and by the great usefulness of the uranium and hydrogen isotopes in the development of atomic energy. In any discussion of this subject, it seems advisable, therefore, to consider briefly the methods employed in isotope separation.

F. Soddy, an early worker in radioactivity and the originator of the name, "isotope," emphasized in 1913 the *chemical* identity of isotopes, even though their mass and nuclear properties differ. For any given isotopic element, the nuclear charges are identical, and therefore the outer electronic structures are nearly identical. From our present knowledge of the mechanisms of separation processes, we know, therefore, that the major separation effect is obtainable through processes dependent on the differences in nuclear mass.

Methods for separating isotopes may be classed under two general types; namely: (1) electromagnetic processes and (2) statistical methods. The first type employs the effect of electric and magnetic fields on the isotopes of the element in question. Although it is theoretically possible to obtain complete separation in one operation, in practice these methods are limited by space charge effects. The second type depends on statistical or average properties of the element in question, such as the relative isotopic abundances of the unprocessed material, the kinetics of the process, and the equilibria between different materials involved, all of which are in turn dependent on small differences in the average behavior of the different isotopic species. This latter type includes diffusion of gases through solid porous materials, diffusion in gravitational or centrifugal fields, electrolysis of a suitable electrolyte, thermal diffusion, fractional distillation, and chemical exchange reactions.

The existence of isotopes was first shown experimentally by Thomson and Aston by the use of mass spectrographs, which are now constructed in many different ways. Instruments of this type were described in the September, 1946, issue of THE RESEARCH ENGINEER in an account of the Georgia Tech mass spectrometer. Briefly, ions of an element are formed by an arc or by electron bombardment and then are accelerated through slits into an evacuated space between the pole faces of an electromagnet. Here, the ions are caused to move in a circular path, the heavier ions transversing a circle of greater diameter than the circle transversed by the lighter ions; collector plates may be suitably placed in the different ion paths for collection of the desired isotopes. This method has been used for the large scale separation of the uranium isotopes, the instrument being known as the "calutron."

If a beam of ions is allowed to fall through an electric field, the velocity of the ions is dependent on the square root of their mass. This dependence causes the light ions to move ahead of the heavy ions and, at a certain distance from their source, they become nearly separated. If a properly timed alternating electric field is applied to these ions, it then becomes possible to deflect the

heavy ions in one direction and the light ions in another and thus effect a separation of isotopes. An instrument employing these principles has been termed an "isotron."[1]

In order to have a measure of the effectiveness of different isotope separation processes, workers in the field have defined a separation factor or coefficient, denoted by α. If n_1 and n_2 are the numbers of light and heavy isotopes, respectively, in a given quantity of an isotopic mixture, and if n_1' and n_2' are the corresponding numbers after a separation has been effected, then

$$\alpha = \frac{n_1'/n_2'}{n_1/n_2} \qquad (1)$$

In other words, α is the ratio of the ratio of the numbers of light and heavy isotopes just after processing to the corresponding ratio just before processing. The value of this α is thus a measure of the efficiency of a given separation process. For the electromagnetic methods, the value of α is quite large and is chiefly limited by the troublesome effects of space charges in the apparatus. In general, processes having large separation factors are seriously limited by low yields.

The statistical methods for separating isotopes have, in general, values only slightly greater than unity (an α value of unity corresponds to no separation). However, a large number of separating units can be combined into a cascade of simple units, with the result that the yield is as good or better than that of the electromagnetic methods even though the separation factor may be quite small for each step of the statistical process. A number of variations of the cascade system have been employed, but in general the fraction containing the light constituent in a simple unit is sent to a succeeding unit for further processing and the fraction containing the heavy constituent is sent to the preceding unit. The number of units required for a given yield and change in the abundance ratio of isotopes depends on the separation factor and the quantity of material handled in each unit. Counter-current flow methods similar to that used in the ordinary fractionation column have been employed, especially in the chemical exchange methods, to materially reduce the number of units.

Of the statistical methods enumerated above, diffusion of gases through solid porous barriers has proved to be one of the most successful. The rate of diffusion through a porous barrier, provided the holes are sufficiently small, is ideally dependent on the square root of the ratio of the molecular weights of the constituents being separated. However, it is neither possible nor practical to obtain this ideal dependence in actual practice. The adjustment of the rate of flow of the gas through the barrier and the minimizing of back diffusion are problems which must be considered in securing the maximum yield with the least amount of apparatus. This method has been employed to separate the isotopes of carbon, nitrogen, oxygen, neon, chlorine, argon, bromine, and uranium.

The distillation of liquids has been used in the separation of the isotopes of certain elements. Originally, Kiesam and van Djik separated the neon isotopes by distilling liquid neon in a counter-current fractionation column similar to that used in chemical separations, and this process has since been employed to separate the isotopes of hydrogen, oxygen, and a number of other lighter elements.

Similar to the distillation method is the chemical exchange method. In this case, nitrogen isotopes, for example, are separated on a commercial scale by exposing ammonia gas to an aqueous solution of ammonium nitrate by means of a counter-current fractionation column. The nitrogen atoms tend to exchange between the two phases, and the heavy nitrogen, N-15, tends to concentrate in the liquid phase, thus affording a means of separation. Effective separation has been obtained by this method for the isotopes of hydrogen, carbon, nitrogen, sulfur, and others of the lighter elements.

Many years ago, it was predicted from studies of the kinetic theory of gases that gases of different molecular weights could be separated by exposing a gaseous mixture to a hot surface and a cold surface mounted parallel to each other in a vertical direction. The theoretical studies of Enskog and Chapman showed that there would be a tendency for one molecular species to con-

[1]For further description of these and other electromagnetic methods, the reader is referred to "Atomic Energy for Military Purposes" by H. D. Smyth, Princeton University Press, p. 187.

centrate in the hot region and another species in the cold region in a mixed gas exposed to such a temperature gradient. Whether the heavy or light constituent concentrates in one temperature region or not is dependent on the nature of the intermolecular forces. If the repulsive forces vary as the inverse fifth power of the distance between the molecules, no separation is obtained, but for those molecules whose intermolecular forces depend on a higher inverse power, separation is possible. A given molecular constituent, in a number of cases, can be made to concentrate either in the cold or the hot region, depending on the temperature and the relative concentrations of all the components.

Clusius and Dickel showed that the thermal diffusion phenomena could be applied to the separation of isotopes. Their apparatus consisted of a vertical tube with a hot wire stretched along the central axis. In the latter apparatus or in the parallel plate arrangement, thermal convection currents are set up, with the hot constituent rising and the cold constituent falling, thus giving rise to another manifestation of counter-current flow. If the ends of the apparatus are closed and the system is allowed to reach an equilibrium state, the samples drawn off at each end of the column will show a marked difference in isotopic composition. This method has been useful in obtaining concentrates of the isotopes of hydrogen, carbon, nitrogen, oxygen, neon, chlorine, xenon, and mercury. Liquid thermal diffusion has been utilized to separate the different isotopic species of uranium hexafluoride.

The imposition of a strong centrifugal field on the isotopic species of a gas or vapor was early shown to result in separation. In this method, the heavier isotopic constituent tends to concentrate at the periphery of the centrifuge and the lighter along the axis of rotation. This process has been enhanced by using long cylindrical centrifuges. Gas is allowed to flow in one direction at the periphery, and in the opposite direction at the center. Thus, a counter-current flow is established which allows good separations, as in the above-mentioned methods. This one has the unique property that the separation is dependent on the difference of isotopic weights and not on the square root of the ratio of the molecular weights of the isotopic species, as in the other methods mentioned. Thus, it is applicable in the case of high atomic weight elements with isotopes having great differences in mass.

The last method to be mentioned here utilizes the electrolysis of a suitable electrolyte which contains the isotopes of the element in question. Since this has been a subject of study by the writer, it will be considered in more detail.

The discovery that the residues in electrolytic cells employed in the commercial production of hydrogen and oxygen contained an increased concentration of heavy hydrogen resulted in the initiation of heavy water production by electrolysis of water containing a suitable electrolyte. The separation factor by this method is very large—in the case of hydrogen isotopes the separation coefficient is often as high as 10-15, depending on such factors as the composition of the electrode materials, the current density employed during electrolysis, the temperature, the concentration of the electrolyte, and the amount of back reaction at the electrode surface. Practically pure deuterium, the isotope of hydrogen of mass 2, has been prepared by this method for study of its properties and for a variety of tracer studies. The study of the electrolytic separation process in the case of hydrogen has been a subject of much experimental and theoretical investigation.

The electrolytic separation of isotopes other than those of hydrogen has received comparatively little attention. Washburn[2] showed that oxygen isotopes were noticeably separated by electrolysis, and Johnston[3] determined the separation factor to be 1.008 for the electrolysis of alkaline solutions with iron electrodes.

First to investigate the electrolytic separation of lithium isotopes were Eucken and Bratzler[4], who were able to set an upper limit of 1.07 for the separation factor. Taylor and Urey[5] obtained a value of

[2]E. W. Washburn, E. R. Smith, and F. A. Smith, *Bur. Stand. J. Research 13*, 599 (1934).

[3]H. L. Johnston, *J. Am. Chem. Soc. 57*, 484 (1935).

[4]A. Eucken and K. Bratzler, *Zeits. f. Physiks. Chemie A174*, 269 (1935).

[5]T. I. Taylor and H. C. Urey, *J. Chem. Phys. 5*, 597 (1937).

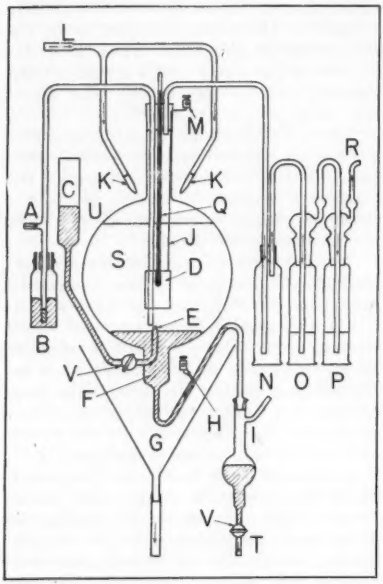

Figure 1. Electrolytic cell for the separation of chlorine and potassium isotopes. A—Nitrogen inlet; B—mercury pressure release; C—mercury reservoir; D—platinum anode; E—jet from which mercury falls on the cathode terminal; I—amalgam reservoir; J—platinum anode lead; K—jets for cooling water; L—cooling water inlet; M—anode terminal; N—trap; O—wash bottle containing sodium hydroxide; P—wash bottle containing acetone; Q—thermometer; R—nitrogen outlet; S—electrolytic solution; T—amalgam outlet; U—four liter pyrex flask; V—stopcock.

1.020; Holleck[6] obtained a value of 1.079; Taylor and Urey[7] obtained another value of 1.039; and, finally, Johnston and C. A. Hutchison[8] obtained a value of 1.055 for the separation factor. The variation in these values was caused by the different materials employed and the varying conditions of the electrolyses. In these electrolyses, a mercury cathode was employed, and, as the lithium was deposited at the mercury surface, an amalgam was formed. By appropriately allowing the mercury to flow through the cell, the lithium was carried from the cell and clean mercury exposed to the electrolytic solution. Differing from the hydrogen electrolyses, the separation factor in the case of lithium was shown to be independent of the cell temperature, the fraction electrolyzed, the magnitude of the current, and of the amount of back reaction of the amalgam with the electrolytic solution.

In regard to the isotopes of chlorine, Johnston and the writer[9] electrolyzed a solution of sodium chloride and obtained a separation factor of 1.0060 for the separation of chlorine isotopes. The writer's recent determination[10] of the separation factor for chlorine, by a slightly different procedure from that above, resulted in the value 1.0063.

In the case of the potassium isotopes, the writer[11] has recently determined the separation factor to be 1.0054. In both the chlorine and potassium electrolyses, the experimental variables listed above, such as the cell temperature, etc., were found to have no measurable effect on the separation factor. It will be observed that, for the elements other than hydrogen, the separation factors are quite close to unity for the electrolytic method, so that isotope separation by this method would be highly impractical.

The apparatus used in the chlorine and potassium work was similar to that of Eucken and Bratzler[4] and to that of Johnston and C. A. Hutchison[8]. The cell consisted of a four liter, round bottom flask, to the bottom of which was sealed an extension which supplied a means for the flowing mercury cathode. The cell contained a rubber stopper at its top through which passed a platinum lead to a platinum gauze anode, a thermometer for measurement of the electrolyte temperature, and glass tubes for passage from the cell of gases which were formed during the electrolyses. The gases were swept from the cell by a stream of nitrogen and absorbed in appropriate

[6]Holleck, *Zeits. f. Elektrochemie 44*, 111 (1938).
[7]T. I. Taylor and H. C. Urey, *J. Chem. Phys. 6*, 429 (1938).
[8]H. L. Johnston and C. A. Hutchison, *J. Chem. Phys. 8*, 869 (1940).
[9]H. L. Johnston and D. A. Hutchison, *J. Chem. Phys. 10*, 469 (1942).
[10]D. A. Hutchison, *J. Chem. Phys. 13*, 536 (1945).
[11]D. A. Hutchison, *J. Chem. Phys. 14*, 401 (1946).

traps; the nitrogen also served to give constant stirring of the electrolytic solution. The mercury for the flowing cathode was supplied from a reservoir near the cell at rates varying from 2.5 to 10 liters per hour. Figure 1 presents a schematic diagram of the cell employed.

At the present time, an electrolytic cell is being operated in the Tech chemistry laboratory for the purpose of separating the isotopes of nitrogen by the electrolytic method. Thus far, we cannot state the exact value of the separation factor, but a small separation has been obtained which corresponds to a separation factor of less than 1.01. In this work, a solution of ammonium chloride is being electrolyzed, and the ammonium ion forms an amalgam at the flowing mercury cathode and is carried from the cell. In this case, a different experimental technique from that of the chlorine and potassium work has to be employed since the ammonium amalgam reacts with the solution as fast as it is formed. To circumvent this obstacle, a porcelain porous tube is used, and the mercury is circulated through the tube. The mercury, in this manner, makes contact with the electrolytic solution through the pores of the tube, but the reaction of the amalgam with the solution is minimized. Since no tubes of proper porosity were available commercially, experimentation was required to obtain suitable tubes. A number of tubes with varying porosities were prepared by the Ceramics Department[12] at Georgia Tech, and these were tested until a tube was found which fulfilled the necessary conditions. Figure 2 shows a schematic drawing of the electrode assembly now being employed in the electrolytic separation of nitrogen isotopes, and Figure 3 presents a picture of the electrolytic cell and the pump for circulation of mercury through the cathode tube.

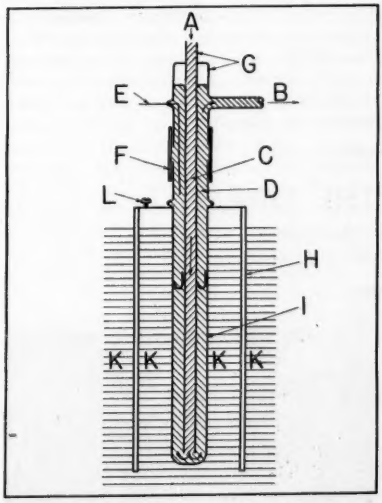

Figure 2. Electrode assembly employed in the electrolytic cell for the separation of nitrogen isotopes. A—Mercury inlet; B—mercury outlet; C—mercury entering the porous tube; D—mercury leaving the porous tube; E—cathode terminal; F—rubber tubing connection; G—glass housing with entrance and exit tube for mercury; H—nickel anode tube; I—porous cathode cup; J—mercury in exit from cathode tube; K—electrolytic solution; L—anode terminal.

[12]These tubes were prepared by Professor W. C. Hansard of the Ceramic Engineering Department at Georgia Tech.

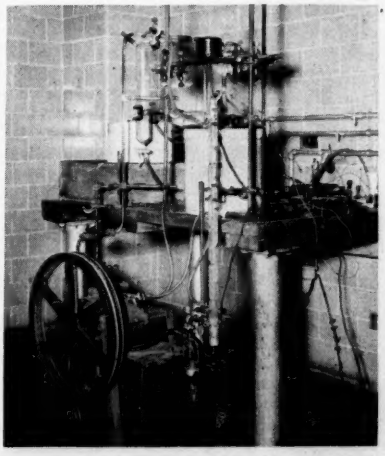

Figure 3. View of the electrolytic apparatus for the separation of nitrogen isotopes.

DISCUSSION

The foregoing paragraphs have been prepared in an attempt to review briefly the more important methods which have been employed to separate isotopes of the chemical elements and to inform the reader concerning Georgia Tech contributions to this phase of fundamental research. With the ever increasing importance of separated isotopes, research in this field assumes something of a more practical nature than was thought a few years.

With the increased availability of radioactive isotopes, one may think that the separation processes described above, which have been used mainly for stable isotope separations, may have become somewhat obsolete. On the contrary, separation of isotopes forms an important step in the study and production of many radioactivity products. Further, in the case of some elements, there do not exist radioactive isotopes with sufficiently long lives to enable their use in tracer studies; e. g., nitrogen, oxygen, and sulfur. Also, some workers find the techniques of stable isotope tracer studies more convenient than those which deal with radioactive materials, and both stable and radioactive isotopes may be used in those cases where it is desired that more than one atom of a given element be labeled in a given molecule. For instance, C-13 and C-14 will have biochemical applications where more than one carbon atom of a molecule must be marked.

It is impossible to predict the future in regard to the separation of isotopes. However, in view of the great differences in nuclear properties of isotopes and the marked increase in nuclear studies, it appears certain that the separation of isotopes of the elements will be of considerable importance.

It often happens that the pursuit of fundamental studies of this and other types may result in an unexpected fundamental or practical application of great importance. Even if this does not occur, "Knowledge is its own reward," and such studies should always be encouraged in any well integrated program of research.

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I have often been asked, "What engineering field do you stress when making acquisitions for the library?" My answer to this always includes: "not only the engineering departments but also those of pure science, chemistry, physics, and mathematics." How can one do engineering research without these basic sciences? How, too, can one say which field of engineering is the most important? Each department of our school contributes in some manner to the research that is being carried on to improve our way of living.

All of us are aware of the importance of aeronautics and the tremendous part it plays in world progress. Our own Daniel Guggenheim School of Aeronautics is recognized within and beyond educational circles for its achievements in the study of aeronautics. Contributory to its success and widespread recognition is our readily accessible collection of aeronautical literature, which has been gathered to aid not only the students but also the research workers who are conducting aeronautical research in the aeronau-

tical laboratories and in the State Engineering Experiment Station. This collection, which is housed in the Guggenheim Building on the campus, includes approximately two thousand books and over four thousand pamphlets. In addition, it contains special files of industrial catalogues, patents, photographs, student technical reports, and numerous wind tunnel reports on various research projects undertaken for the aeronautical industry and governmental agencies.

The collection is also valuable for its files of journals, transactions, reports of important aeronautical societies, and bibliographical materials. Of special note are its files of Reports and Memoranda of the Aeronautical Research Committee of Great Britain and documents of the National Advisory Committee for Aeronautics, our governmental agency for the promotion of aeronautics.

These aeronautical items, both documents and books, are made far more valuable and available through the indexes maintained. There are two card catalogues in the aeronautical library, one for the books (a duplicate of the one housed in the School's main library) and a special one for periodical articles and pamphlet material. The latter index, which now totals approximately 35,000 cards, is the product of the cooperative efforts of students, instructors, and the departmental library staff over a number of years, and it has proved a most useful tool in graduate study and research. Subject breakdowns employed in building this index are responsible for its great value, particularly in the fields of aerodynamics and structures. It might be interesting to note that this subject-headings list was examined at the annual meeting of the Special Libraries Association in June, with the object of incorporating it in the consolidation of the many special aeronautical subject-headings lists which are now in existence, so that one standard, uniform list may be compiled. Former students and staff members who now hold positions in industry and at other institutions have often returned to praise our "working index" of aeronautical material.

Another aeronautical index of vast potential proportions, one which may prove to be an important and valuable addition to our collection, has recently been acquired from the Army Air Forces. We are busily assembling it from a series of cards, which ae part of the Air Documents Index now in preparation at Wright Field. It has evolved (and is steadily growing) as a result of the classification of tons of foreign aeronautical documents collected through the combined efforts of the Army Air Forces, U. S. Navy, and British Intelligence (some 500,000 items having been recently moved from London to Wright Field and from the work of the Air Documents Research Center, U. S. Air Forces in Europe to Air Documents Division, Air Materiel Command, Wright Field). This material is being processed in order that all the foreign aeronautical items (particularly German and Japanese) which are of any value whatsoever will be catalogued and may become available, through a plan of dissemination, to the aeronautical industry, research agencies, and educational institutions. Having agreed to establish and maintain one of these catalogue files, which will approximate 300,000 cards when complete, we have been designated as a depository for the Air Documents Index in this area.

As mentioned, the cards have begun to arrive, an initial shipment of 20,000 having been received several months ago; four subsequent shipments have brought the present total to more than 30,000. Efforts are being made to get these in usable shape as rapidly as possible. Each card contained in the index carries an abstract of the item catalogued. In addition, complete translations of these items will be available as rapidly as they are reproduced through the cooperative efforts of the participating agencies. Some 75 of these translations have already been received, together with other miscellaneous related technical documents.

This branching out—the acceptance of the Air Documents Index, the translated documents, bibliographies on special subjects, the German-English dictionary of aeronautical terms, and other material being directed to us from the Air Documents Division at Wright Field—further establishes our aeronautical collection as being unique and of incalculable value to the Southeast.

The following are some of the books and journals which comprise our aeronautical collection; a list such as this may be tedi-

ous reading, but it is indicative of the scope of such collections:

BOOKS

Abhandlungen aus dem Aerodynamischen Institut an der Technischen Hochschule Aachen, 1921-1934; *Aerosphere: Including World's Aircraft Engines with Aircraft Directory*, 1939-1946; *Air Annual of the British Empire*, 1929-1937; *Aircraft of the Fighting Powers*, 1941-1944; *Aircraft Yearbook*, 1919-1946; *All the World's Aircraft*, 1916-1946; *American Aviation Directory*, 1940-1946; *Australian Council for Aeronautics Reports*, 1944-1946; Guiseppe Boffito, *Biblioteca Aeronautica Italiana Illustrata;* Leonard Bridgman, *Aircraft of the British Empire; International Index to Aeronautical Technical Reports*, 1933, 1937, 1938; Willard Kelso Dennis, *Recent Periodical Articles*, 1943-1944; *Deutsche Versuchsanstalt fur Luftfahrt. Berlin-Adlershof. Jahrbuch*, 1912-1933; Charles Dollfus, *Histoire de l' Aeronautique;* William Frederick Durand, *Aerodynamic Theory; A General View of Progress* (Six Volumes); *Erfebnisse den Aerodynmischeon Versuchsanstalt zu Gottingen* (Four Volumes); Robert Gruss, *Les Flotte de l'Air; Inte:avia ABC 1936, International Reference Book of Aviation; Jahrbuch der Deutchen Luftfahrtforschung unter Mitwirkung des Reichsluftfahrtministeriums der Luftfahrtforschungsanslaten und-Institute, Sowie der Lilienthal-Gesellschaft*, 1937-1938; *Die Arbeiten des Preussichen Aeronautischen Abservatoriums bei Lindenberg, Braunschweig Druck von F. Vieweg and sohn*, 1906-1929; *The History of Flight;* Ministere de l'Air, *Publications Scientifique et Techniques*, 1931-1939; *Rijks-Studiedienst voor de Luchtvaart Verslagen en Verhandelinger van den Ryks-Stiedienst voor de Luchlvaart*, 1921- 1925, 1927; New York Public Library, *History of Aeronautics;* Henry Christensen Pavian, *Experimental Aerodynamics;* Roland H. Spaulding, *Books on Aeronautics; Tokyo University Aeronautical Research Institute Journal*, 1935, and *Reports*, 1921-1937; U. S. Aeronautics Branch, *Air Commerce Bulletin*, 1929-1939; U. S. Army Air Forces, *Bibliography of Rotary Wing Aircraft;* U. S. Library of Congress, *Aeronautic Americana;* U. S. Library of Congress, *The Aeronautical Index*, 1939-date; U. S. National Advisory Committee for Aeronautics, *Annual Report*, 1915-1941; U. S. National Advisory Committee, *Bibliography of Aeronautics*, 1909-1932; U. S. Works Projects Administration, *Bibliography of Aeronautics*, 1936-1941; and *Who's Who in Aviation.*

JOURNALS

Aero Digest (1928-date); *Aeronautica; Revista Mensile Internasionale Illustra; Organo die Volatori e Costruttore Aeronautici d'Italia* (1927-32); *Aeronautical Engineering Review* (1942-date); *Aeronautics* (1939-1942); *Aeronautique; Revue Mensuelle Illustree* (1929-1939); *Aerophile; Revue Technique Etpratique et la Locomotion Aereinne* (1924, 1942, 1943-date); *Aeroplane* (1911 - date); *Aerotecnica* (1939); Air News (1941-date); *Air Progress* (1938-1942); *Air Trails* (1943-1944); *Aircraft Engineering* (1929-date); *Aircraft Production* (1940-1944); *Airports* (1928-1931); *American Aviation* (1938-date); *Astronautics* (1930-1940); *Aviation* (1931-date); *Civil Aeronautics Journal* (1940-1943); *Deutsche Luftwacht* (1935-1939); *Flight* (1909-date); *Flugsport* (1908-1926); *Journal of the Aeronautical Sciences* (1934-date); *Luftfahrschung* (1928-1944); *Revista Aeronautica* (1932-1938); *Royal Aeronautical Society Journal* (1913-date); *Soaring* (1937-date); *Southern Aviation; Blue Book of Aeronautical Activities in the Southern States* (1930-1933); *Southern Flight* (1938-1944); *Technique Aeronautique* (1938 - 1939); *Western Flying* (1929-1944); *Wissenschaftliche Gesellschaft fur Luftfahrt. Berichte und Abhanklungen* (1920-1926); and *Zeitschrift fur Flugtechnik* (1910-1933).

Our aeronautical library has been discussed here as a typical example of the engineering and scientific service which is stressed by the Georgia Tech library. Similar collections in other fields will be mentioned in future articles in this series.

Mrs. Crosland is at present in Europe, acquiring additional material for the Georgia Tech library. The next installment of REPORT FROM THE LIBRARY *will contain excerpts from letters describing her experiences on this somewhat unique venture.*